

CHAPTER 2

DECOMMISSIONING METHODS

2-1. Decommissioning methods

The US. Nuclear Regulatory Commission (NRC) final rule for decommissioning criteria published in 10 CFR. 30, 40, 50, and 70 addresses methods and alternatives. This rule defined decommissioning as “to remove a facility safely from service and reduce residual radioactivity to a level that permits release of the property for unrestricted use and termination of license.” The rule also discussed the three decommissioning alternatives leading to unrestricted use. These are DECON, SAFSTOR, and ENTOMB. All three alternatives or combinations of these alternatives lead ultimately to unrestricted use, although SAFSTOR and ENTOMB defer reaching unrestricted use until after a storage period. Ultimately, all material having associated radioactivity in excess of acceptable residual levels must be removed from the facility or site before it can be declared released for unrestricted use and the operating and possession licenses terminated.

a. DECON. Decontamination, or DECON, is the alternative in which contaminated equipment, structures, and portions of a facility are physically removed from the site or are cleansed of radioactive contaminants by chemical or mechanically abrasive means such that the remaining property can be released for unrestricted use shortly after cessation of operations. Implementation of DECON can result in substantial amounts of low level radioactive waste requiring removal and disposal. DECON is the preferred approach to decommissioning. DECON has certain benefits in that it would prepare the property for unrestricted use in a much shorter period than SAFSTOR or ENTOMB, with acceptable effects on occupational and public health and safety. Decommissioning a facility and releasing the property for unrestricted use eliminates the potential problems that may result from having an increasing number of sites contaminated with radioactive material. This procedure also eliminates potential health, safety, regulatory, and economic problems associated with maintaining a nuclear facility. Because of the importance of decontamination in decommissioning, this topic is discussed in detail in chapter 3.

b. SAFSTOR. Nuclear facilities can be placed and maintained in such condition that the structure and contents can be safely stored and eventually decommissioned (deferred decommission), permitting release for unrestricted use. In general, in preparing a facility for the SAFSTOR option the structure may be left intact, except that all nuclear fuels, radioactive fluids, and wastes must be removed from the site. In some cases where off-site disposal is unavailable, on-site storage of solidified waste may be necessary (see Section 2.4). The deferred completion of decommissioning through the use

of SAFSTOR can be a viable alternative and should be considered when any of the following conditions exist:

(1) When the low level waste (LLW) disposal capacity is inadequate to implement the DECON alternative.

(2) When an adjacent nuclear facility would be adversely affected if the DECON alternative were implemented.

(3) When a positive benefit would be derived through a limited period of radioactive decay. This positive benefit would be determined by comparing the total cost and radiation exposure resulting from DECON to that resulting from the SAFSTOR.

c. ENTOMB. When using the ENTOMB decommissioning option, all nuclear fuels, radioactive fluids, and wastes are removed from the site and all structural and mechanical materials and components not decontaminated to acceptable levels are encased in a structurally long-lived material such as concrete. The entombed structure is appropriately maintained under continued surveillance until the radioactivity decays to a level permitting unrestricted release of the property. The ENTOMB alternative has limited application because all radioactive contaminants must decay to levels that will allow the facility to be declared released for unrestricted use within 100 years. The maximum duration of deferred decommissioning should not be greater than 100 years, as this is considered a reasonable period of time for reliance on institutional control. This will require careful characterization of the radioactive materials to remain. A concern with this approach to decommissioning is the possibility that, during the entombment period, the criteria on allowable levels of residual contamination may change, or even the results of the initial radiation characterization could be challenged and disqualified. Dismantlement of the entombed facility may then be required resulting in very large costs.

2-2. Selection of decommissioning alternatives

A decommissioning plan can use any one of three methods described in paragraph 2-1. Alternatively, a plan can be developed to use combinations of the three methods, where a portion of the facility is decommissioned immediately with the rest delayed. In the development of a plan, alternatives should be postulated which include the three decommissioning methods separately and one or more viable combinations of the methods. Each alternative must be evaluated individually to qualify, to the best extent possible, the result of implementation with regard to public health, occupational safety, environmental impact, waste management, initial investment, and long term costs. Public and worker health relate

to the level of potential exposure to direct and airborne radiation. Environmental impact and waste management are functions of the quantities and types of radioactive nuclides and associated half-lives. Costs are driven by various factors all of which must be considered when selecting the best alternative. The final selection is made based on the alternative which will best accommodate the safety, environmental, waste, and cost issues. An assessment of the order of importance of these factors is a necessary part of the decision process, which can only be made on a case by case basis. Factors important to the evaluation and selection of decommissioning alternatives include the following.

a. Available Waste Disposal Capacity. Upon termination of operations at a facility, there may be inadequate LLW disposal capacity available at approved disposal sites to implement the DECON alternative. Decontamination methods typically result in large quantities of LLW requiring disposal. Therefore, it would be necessary to employ the SAFSTOR approach while additional disposal capacity is being provided or to permit a reduction in radioactive waste through the decay of the radioactive contaminants, provided the radionuclides present have half-lives which make this approach feasible.

b. Proximity of Other Facilities. There may be another operating facility in close proximity to the nuclear facility that has just ceased operation. The decommissioning of the shutdown facility using the DECON alternative may adversely affect the operating facility. Also, it may be easier or less expensive to delay decommissioning until all adjacent facilities can be finally decommissioned at once.

c. Critical/Abundant Radionuclides. The critical/abundant radionuclides, that is, the particular radionuclides most critical to decommissioning, must be identified and addressed in selection of alternatives. As an example, cobalt-60 which is prevalent in power reactors, has a half-life of 5.3 years. If SAFSTOR is implemented for a period of 35 years, a 99% reduction of cobalt-60 radionuclide will result. (Note: This represents a situation where the cobalt-60 is not part of a decay chain; that is, it does not result from the decay of another radionuclide.) Thus, in such situations where contamination levels are large, use of SAFSTOR can result in large dose reduction to workers. However, in situations where the half-life of the critical/abundant radionuclide is long, such as uranium, little benefit in dose reduction is derived from the SAFSTOR or ENTOMB decommissioning alternatives. Reference appendix C for a discussion on radionuclide half-life and calculation of concentration changes over a period of decay.

d. Implementation Costs. The cost of implementing a given alternative must be carefully evaluated. The cost differential between immediate and deferred decommissioning alternatives, however, can be difficult to estimate and is definitely site-dependent. Although the cost for immediate decommissioning can be estimated within an

acceptable degree of accuracy, there are uncertainties in estimating the cost of controlling a site for long periods of time. In addition, factors such as exceedingly high annual escalation of LLW disposal rates can negate any postulated savings from the deferred decommissioning alternative, even if reduced waste volumes are a result of the deferred decommissioning. The burial rates at one disposal facility increased by a factor of 25 in a 13 year period. In evaluating the cost of deferred decommissioning, factors to be considered are as follows:

- (1) Security systems including guards, fences including installation and maintenance costs, and electronic surveillance including installation and maintenance costs.
- (2) Maintenance of facility access within the controlled area including roads, bridges, and parking.
- (3) Maintenance of the facility enclosure for weathering of the construction materials.
- (4) Collection, sampling, and remediation efforts, if necessary, until decommissioning is complete.
- (5) Monitoring and maintenance of the radiation confinement boundaries within the facility.
- (6) Maintenance of access ways within the facility for inspection.
- (7) Maintenance of lighting and ventilation systems as well as any support systems.
- (8) Facility inspection.
- (9) Radiation surveys both inside and outside the facility.
- (10) Decommissioning costs that can increase rapidly during the storage period - in particular, the potential escalation in the cost of LLW disposal.
- (11) Reduced LLW disposal cost because of reduced waste volume resulting from radioactive decay.
- (12) Reduced LLW disposal surcharge cost because of radioactive decay. This is not a reduction in base rate disposal costs but surcharges added to the base rate based on the radiation level and/or unit inventory associated with the waste.
- (13) The benefits resulting from reduced personnel exposure during decommissioning because of lower radiation levels in work areas due to radioactive decay of the contaminants.

2-3. Standards for acceptable residual radiation levels, concentrations, and contamination

The ultimate objective of any decommissioning program, whether performed immediately after termination of operations or deferred for some period of time, is to have the facility declared released for unrestricted use and the NRC license terminated. To achieve this goal, the residual radioactivity levels associated with the decommissioned facility must be below acceptance limits. At this time, there are few standards on acceptable residual radiation levels. Those standards that do exist address only specific topics and not the entire scope of a decommissioning effort.

a. Nuclear Regulatory Commission Guidelines. The NRC has published values for acceptable residual surface

contamination levels and is developing standards for residual radiation in decommissioning.

(1) Values are presented in the NRC's "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use of Termination Operating Licenses for Byproduct or Source Materials," and in Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors." The NRC values are in Table 2-1.

(2) The NRC is also developing standards for residual radiation in decommissioning. NRC policy defines acceptable radiation level as 10 mrem/yr, a base level which is subject to change but which may be used on an interim basis. The policy does not assert an absence or threshold of risk at low radiation dose levels but establishes a baseline level of risk beyond which further government regulation to reduce risks is unwarranted. It also establishes a consistent risk framework for regulatory exemption decisions should radiation levels exceed 10 mrem/yr at the time of decommissioning.

(3) ALARA (as low as is reasonably achievable) is applied in granting exemption to radiation levels which are below 100 mrem/yr but which exceed the acceptable level of 10 mrem/yr. ALARA means that every reasonable effort must be made to maintain radiation exposures as far below applicable dose limits as is practical consistent with the purpose for which the activity is undertaken. It takes into account the state of technology, the economics of improvements to public health and safety benefits, and other societal and socioeconomic considerations in the public interest. Considerations in application of ALARA are discussed in 10 CFR 20.

(4) NUREG/CR-5512, "Residual Radioactive Contamination from Decommissioning" describes a generic method for evaluating conditions of unrestricted release of slightly radioactive material in buildings and soil following decommissioning of licensed facilities. Major pathways of direct exposure to penetrating radiation are considered and a technical basis for translating contamination levels to annual dose is provided. Pathway analysis varies from site to site. Examples of pathways that must be considered include:

- (a) Direct radiation from residual radioactivity.
- (b) Airborne radioactivity from windblown contaminated soil.
- (c) The food pathway, that is, eating food grown at the site of a decommissioned nuclear facility or eating meat of animals that grazed on such areas.
- (d) Any possible water pathway, such as swimming in a pond which receives water runoff from a decommissioned nuclear facility.
- (e) Any dose received as a result of using recycled decontaminated materials from the decommissioned facility.

b. Environmental Protection Agency Standards.

(1) The U.S. Environmental Protection Agency (EPA) has published emission standards for the release of

radionuclides into the air in the revised 40 CFR Part 61. Consult that standard when developing applicable designs.

(2) The EPA provides promulgated soil standards for uranium mill tailing sites. These soil standards are presented in 40 CFR 192.

(3) The EPA is responsible for developing standards establishing acceptable levels of residual contamination. Until such standards are developed, guidance should be obtained from the NRC.

c. Survey Requirements. The progress of the decommissioning effort must be tracked and documented to ensure success. This is accomplished in part by radiological surveys

(1) Radiological surveys should be made to establish the baseline radiation and contamination levels prior to the initiation of construction efforts. Radiation surveys should also be conducted to obtain baseline data when an existing facility is rehabilitated or expanded.

(2) Prior to and throughout the decommissioning process, surveys will be used to evaluate the success of decontamination efforts, and to show that the radioactive materials involved are under control. Refer to Section 6-5 on this issue.

(3) Radiological data will be collected after decommissioning is complete to obtain a final result.

d. Survey Procedures. The following guidelines are provided for the conduct of radiation surveys:

(1) An accepted method for conducting this type of survey is to establish and document a grid system for the site. Direct radiation measurements should be made on contact and at a height of one meter at each grid intersection using portable radiation-survey instrumentation. The grid should be designed such that it can be duplicated in the future, thus permitting radiation measurements to be made after decommissioning for comparison with the original direct radiation measurements. In addition to survey instrument measurements, cumulative-radiation measuring devices such as thermoluminescent dosimeters may be positioned both on site and in adjacent areas offsite to determine exposure levels for long-term background direct radiation. These original radiological data should be incorporated into the Facility Decommissioning Plan to ensure that the information is available at the time of decommissioning.

(2) Contamination surveys of the facility, such as wipe tests, should be performed as necessary throughout the decommissioning process.

(3) For some sites, it will be necessary to sample various environmental components as well as make direct radiation surveys. Collection of environmental samples is required for siting nuclear power plants and is recommended for other facilities whose releases could result in water, sediment, and soil contamination. Air, water, vegetation, sediment, and soil samples should be collected and their locations documented. The samples then should be evaluated using laboratory instrumentation to determine the quantity of radioactive material present in these

environmental components and, if required, the identity of the various radionuclides present. The results of these surveys should be incorporated into the Facility Decommissioning Plan to ensure that the information is available at the time of decommissioning.

2.4. Radiological standards for on-site contingency storage

The retention of radioactive waste at a nuclear facility would prevent the facility from being declared decommissioned and available for unrestricted use.

a. Implications. The retention of radioactive waste at any nuclear facility results in the following:

- (1) The potential exists for significantly higher expenses due to rapid escalation of LLW disposal costs.
- (2) Costs are incurred to provide adequate and safe on-site storage of low-level radwaste.
- (3) The possibility of changing regulations on acceptable waste forms and packaging could result in waste having to be reprocessed and repackaged prior to its being shipped to a disposal facility.
- (4) The retention of radioactive waste at a site for an extended period is likely to result in an adverse public reaction.

b. Standards and Requirements. Should it be deemed necessary that interim (5 years or less) on-site storage of low-level radioactive waste is needed to support a decom-

missioning effort, guidance on providing such storage is given in SECY-81-383; NUREG-0800, Appendix 11.4-A; and Radiological Safety/Guidance for On site Contingency Storage Capacity, NRC Generic Letter 81-38. These references should be reviewed in planning for on-site storage of low-level radwaste. Provided below is a summary of radiological standards and requirements that should be addressed.

- (1) ALARA design features.
 - (2) Off-site radiation exposure limits as set forth in 40 CFR 61 and 190. The contribution from direct radiation should be limited to about 1 mrem per year.
 - (3) Effluent monitoring of gases and liquids as required by 10 CFR 50, Appendix A.
 - (4) An analysis of postulated accidents. The resulting calculated exposures should be 10 percent of the limits established in 10 CFR 100.
 - (5) Prevention of contaminant spread due to weather and environmental conditions expected at the site and the potential for fires.
 - (6) Surveillance and security.
 - (7) Maintenance of detailed records of all waste material in storage.
- c. Burial of Waste.* Radioactive wastes will not be buried at nuclear facilities. This includes both during the operational life of the facility and decommissioning.

Table 2-1. Acceptable Surface Contamination Levels

Nuclide ^a	Average ^{bcf}	Maximum ^{bdf}	Removable ^{bef}
U-nat, R-235, U-238, and associated decay products	5,000 dpm α /100 cm ²	15,000 dpm α /100 cm ²	1,000 dpm α /100 cm ²
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, 227, I-125, I-129	100 dpm/100 cm ²	100 dpm/100 cm ²	20 dpm/100 cm ²
Th-nat, Th-232, Sr-90 Ra-223, Ra-224, U-232 I-126, I-131, I-133	1,000 dpm/100 cm ²	3,000 dpm/100 cm ²	200 dpm/100 cm ²
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000 dpm $\beta\gamma$ /100 cm ²	15,000 dpm $\beta\gamma$ /100 cm ²	1,000 dpm $\beta\gamma$ /100 cm ²

^aWhere surface contamination by both alpha-and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

^bAs used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

^cMeasurements of average contaminant should not be averaged over more than 1 square meter. For objects with less surface area, the average should be derived for each such subject.

^dThe maximum contamination level applies to an area of not more than 100 cm².

^eThe amount of removable radioactive material per 100 cm² of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionately and the entire surface should be wiped.

^fThe average and maximum radiation level of surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.